

5. Geochemical Factors Governing Inorganics/Metal Mobility in the Environment

CHEMICAL REACTIONS OF URANIUM IN GROUND WATER AT A MILL TAILINGS SITE

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Journal of Contaminant Hydrology, Vol 34 No 4, p 343-361, 1998

Uranium adsorption and precipitation under the influence of temperature and pH changes was studied in samples of soil and ground water from the mill tailings disposal site near Tuba City, Arizona. The uranium concentration is up to 20 times the maximum concentration allowed for ground water in the United States. Batch adsorption and leaching experiments with sandstone and contaminated ground water at the in situ ground-water temperature, 16 degrees C, show that uranium is not adsorbed. However, adsorption of uranium is observed when the contaminated ground water is diluted with carbonate-free water. Storage of undiluted ground water to a higher temperature of 24 degrees C, the ambient temperature in the laboratory, causes coprecipitation of uranium with aragonite and calcite. An improved understanding of the chemistry of uranium in ground water can be used to select the optimum remediation strategy, and the results of the study are discussed in terms of ground water treatment methods such as natural flushing, in situ biotreatment, steam injection, and pump and treat.

CONTAMINANTS MOBILITY IN ACID-GENERATING WASTES/SUBSOIL SYSTEMS

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Journal of Environmental Science and Health, Part A: Environmental Science and Engineering, Vol 294, p 745-752, 31 May 1994

Redox reactions and microbial activity are considered as the principal causes for acid generation in the majority of solid waste disposal sites. The generated acid liberates hazardous elements from the solid phase by enhancing dissolution/desorption reactions. Addition of alkaline materials to acid-generating wastes can help, at least temporarily, in the immobilization of these elements. Depletion of alkalinity in the wastes, or in the underlying soils, may result in the migration of contaminants to ground aquifers. The alkaline capacity of fine till (a type of subsoil used to embank uranium tailings) was determined to be 0.02 g (as NaOH)/g of till. The tailings leachate was examined and found to be acidic (pH 2.0), probably due to pyrite oxidation accelerated by *T. ferrooxidans* bacteria. The interaction of such metals-laden acidic leachate with the fine till was also examined, by using Cd-109 as a tracer. For a liquid/solid ratio of 10, it was found that cadmium retention on fine till was effected by precipitation and sorption. Cd retention was characterized as being pH dependent and reversible. This revealed some information about the weak linkages between sorbed Cd and the outer mineral surface, and Cd-precipitate redissolution under acidic conditions. Upon examining cadmium speciation (at pH 6.0), it was found that 40% of Cd was being sorbed and 50% of it was being precipitated.

MERCURY IN SOILS AT THE ABANDONED RED DEVIL MINE IN SOUTHWEST ALASKA

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International Conference on Heavy Metals in the Environment, 6-10 August 2000, Ann Arbor, MI
Elsevier Science Publishers, Oxford, UK [abstract only]

The behavior of mercury in soils is important in understanding the overall biogeochemical cycle of mercury. Much of the mercury in aquatic systems can originate from terrestrial sources. We have been measuring total Hg (THg), methylmercury (MeHg) and Hg(II) for four years in soil samples collected from the Red Devil mercury mine in southwest Alaska. The mine was once Alaska's largest mercury producer and is currently a high priority site for waste removal and remediation activities by the BLM. For selected samples we have also conducted radiotracer experiments to measure the formation and degradation of MeHg. Consistently high levels of THg (up to 3,200 mg/kg), MeHg (up to 8.4 g/kg, and Hg(II) (up to 16.0 mg/kg) were measured at various locations around the mine site. Whereas upstream and background concentration values for all three Hg species are significantly lower, the proportion of MeHg to THg at the upstream and background sites is much higher (up to 0.225%) than at the mine sites (less than 0.001%). We observed both methylating and demethylating activities in soils from the mine site and from upstream and background sites. Methylmercury production, as measured by the amount of added ^{203}Hg that was methylated during sample incubation, was consistently higher at the upstream and background sites than at the mine sites. Methylmercury degradation, as measured by the amount of added $^{14}\text{CH}_3\text{Hg}$ that was demethylated during sample incubation, was more active in the mine sites than in the upstream and background sites. We speculate that mercury resistant bacteria that produce enzymes required for MeHg degradation processes are more likely to be active in sites highly contaminated with mercury such as near the mine than at the relatively uncontaminated upstream or background sites.

PARTITIONING OF TRACE METALS BETWEEN CONTAMINATED STREAM WATERS AND MANGANESE OXIDE MINERALS, PINAL CREEK, ARIZONA

Best, J.E.; K.E. Geiger; P.A. O'Day

U.S. Geological Survey Toxic Substances Hydrology Program: Proceedings of the Technical Meeting, 8-12 March 1999, Charleston, South Carolina. Volume 1: Contamination From Hard-Rock Mining

U.S. Geological Survey Water-Resources Investigation Report 99-4018A, p 227-238, 1999

Copper mining activities near a perennial stream in central Arizona have produced high trace metal concentrations in addition to cobalt, copper, nickel, and zinc, in solution and ubiquitous precipitation of manganese oxide minerals as coatings on stream sediments. Analyses of coating samples at two sites along the stream indicate bulk manganese concentrations of 7.2 to 29.4 wt. %. At the upstream site (R2b), manganese minerals (identified by XRD) are primarily birnessite and rancieite with minor amounts of rhodochrosite, pyrolusite, cryptomelane, and franklinite. At a site approximately 5 kilometers downstream (9272a), the manganese mineral assemblage is dominantly pyrolusite with smaller amounts of todorokite, birnessite, rhodochrosite, and kutnahorite. Maps of elemental distributions in coatings from site R2b (using SIMS and LA-ICP-MS) show strong correlations of cobalt to manganese and correlation of copper to both manganese and iron. Samples from site 9272a show that trace metal concentrations relative to total manganese are lower than at site R2b and that calcium and iron are associated with manganese. Trace metal distributions in samples from R2b and 9272a are attributed to cation substitutions in birnessite, rancieite, and todorokite. Activities of dissolved metals decrease downstream as pH increases and metals are removed by precipitation. Thermodynamic equilibrium between stream waters and end-member

manganese oxides predicts mineralogical conversion from metastable birnessite and todorokite to stable pyrolusite, consistent with observations of the stream sediments. Manganese phases may persist metastably by substitution of trace metals into the mineral structure. Conversion to thermodynamically stable manganese oxide minerals may exclude trace metals and potentially remobilized them. More Info: <http://toxics.usgs.gov/pubs/wri99-4018/Volume1/index.html>

GEOCHEMISTRY AND REACTIVE TRANSPORT OF METAL CONTAMINANTS IN GROUND WATER, PINAL CREEK BASIN, ARIZONA

Brown, James G.; Pierre D. Glynn; R.L. Bassett

U.S. Geological Survey Toxic Substances Hydrology Program: Proceedings of the Technical Meeting, 8-12 March 1999, Charleston, South Carolina. Volume 1: Contamination From Hard-Rock Mining

U.S. Geological Survey Water-Resources Investigation Report 99-4018A, p 141-154, 1999

Activities related to more than a century of large-scale copper mining in the Pinal Creek Basin in central Arizona have contaminated the regional alluvial aquifer and perennial streamflow with acidity and metals. Water-chemistry and solid-phase analyses and computer-aided geochemical modeling were used to understand the evolution of the ground-water plume between 1984 and 1998. The ground-water plume consists of three hydrochemical zones: (1) an acidic zone, which contains large concentrations of metals and has a pH that ranges from 3.6 to about 5; (2) a transition zone where carbonate-mineral dissolution causes pH to increase to above 5, which results in the precipitation of iron hydroxide and the adsorption of trace metals such as nickel and zinc; and (3) a neutralized zone, which contains large concentrations of manganese, calcium, and sulfate, and has a pH of about 6 to 7. Inverse geochemical modeling using NETPATH revealed that, in addition to calcite dissolution, silicate dissolution was required to account for the mass transfers of calcium and magnesium across the transition zone. Analysis of the measured changes in plume geochemistry was aided by PHREEQC reactive-transport modeling, which helped determine that oxidation-reduction reactions were significant in the acidic zone of the plume through the late 1980's. The local equilibrium assumption required by reactive-transport modeling probably was invalid for oxidation-reduction reactions that involved manganese and, to a lesser extent, neutralization reactions that involved calcite. Sensitivity analyses indicated that the rate of advance of the pH front was highly sensitive to the initial calcite concentration, and that ground water along a flow path near the base of the alluvium was in partial or indirect contact with the atmosphere, possibly through mixing with shallower water. More Info: <http://toxics.usgs.gov/pubs/wri99-4018/Volume1/index.html>

HYDROLOGIC AND GEOCHEMICAL FACTORS AFFECTING METAL-CONTAMINANT TRANSPORT IN PINAL CREEK BASIN NEAR GLOBE, ARIZONA

Brown, J.G.; J.W. Harvey

U.S. Geological Survey Toxic Substances Hydrology Program: Proceedings of the Technical Meeting, 20-24 September 1993, Colorado Springs, Colorado

U.S. Geological Survey Water-Resources Investigations Report 94-4015, p 1035-1042, 1996

RESEARCH ON ACIDIC METAL CONTAMINANTS IN PINAL CREEK BASIN NEAR GLOBE, ARIZONA

Brown, J.G.; R. Brew; J.W. Harvey

U.S. Geological Survey Fact Sheet FS-005-97, 1997

A FIELD INVESTIGATION OF TAILINGS RESUSPENSION IN A SHALLOW WATER COVER
Catalan, L.J.J.; J.F. Boucher (Noranda, Inc., Pointe Claire, PQ, Canada); E.K. Yanful; M.L. Shelp (Univ. of Western Ontario, London, ON, Canada)

Fifth International Conference on Acid Rock Drainage, 20-26 May 2000, Denver, CO

Society for Mining, Metallurgy, and Exploration, Inc. (SME), Littleton, CO. ISBN: 0-87335-182-7. Vol 2, p 921-932, ©2000

Shallow water covers for preventing acid production in tailings are based on the principal of minimizing oxygen availability. Resuspension of material from the tailings bed may result in increased oxidation and metal releases since dissolved oxygen is at near saturation levels in the water cover. Resuspension can be caused by waves and currents strong enough to mobilize the surface of the tailings bed. Tailings resuspension was measured with sediment traps in the Upper Cell of the Heath Steele site near Miramichi, NB, Canada. Although significant amounts of resuspended tailings were collected in all traps, analysis of resuspended solids and bed tailings suggests that for the observed wind conditions resuspension did not occur at locations where the water cover depth was great or equal to 1.0 m. Currents were likely responsible for the transport of resuspended tailings from shallower areas to locations where the water cover was deeper than 1.0 m.

RELATIONS AMONG SULFATE, METALS, SEDIMENT, AND STREAMFLOW DATA FOR A
STREAM DRAINING A COAL-MINED WATERSHED IN EAST-CENTRAL PENNSYLVANIA

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Fifth International Conference on Acid Rock Drainage, 20-26 May 2000, Denver, CO

Society for Mining, Metallurgy, and Exploration, Inc. (SME), Littleton, CO. ISBN: 0-87335-182-7. Vol 1, p 401-410, ©2000

Streamflow and water-quality data for the northern part of Swatara Creek, which drains a 112-km² area in the Southern Anthracite Field of east-central Pennsylvania, indicate iron, copper, and lead, and to a lesser extent manganese and zinc, are transported with suspended particles during stormflow conditions. During stormflow conditions, concentrations of these constituents typically peak prior to peak stream stage as a result of scour and transport of streambed deposits. In contrast, sulfate is transported mostly as a dissolved ion. Concentrations of sulfate, specific conductance, and pH are inversely related to streamflow, indicating dilution and acidification during stormflow. This effect is attributed to the mixing of poorly buffered stream water having pH 6.0-6.5 with weakly acidic storm runoff having pH 4.0-4.5 and low dissolved solids.

HYDROGEOCHEMISTRY OF GROUNDWATERS ASSOCIATED WITH EPITHERMAL
HOT-SPRING-TYPE HG DEPOSITS

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Fifth International Conference on Acid Rock Drainage, 20-26 May 2000, Denver, CO

Society for Mining, Metallurgy, and Exploration, Inc. (SME), Littleton, CO. ISBN: 0-87335-182-7. Vol 1, p 379-388, ©2000

This study characterizes the hydrogeochemistry of groundwaters near opalite-hosted epithermal hot-spring type mercury deposits in the Ivanhoe mining district, Elko County, Nevada. Local groundwaters generally range from ca-HCO₃ to Ca-Mg-Na-SO₄ type waters with background mercury concentrations ranging from 0.014 to 0.32 µg/l. Leaching experiments conducted on mineralized rocks, using typical water chemistries to represent local groundwaters, yield total mercury concentrations ranging from 6.3 µg/l to 27.4 µg/l after one year of reaction. Geochemical modeling indicates dissolved mercury is dominated by

Hg₀(aq) and that precipitation of quicksilver controls mercury concentrations to an upper limit of 63 µg/l.

THE EFFECT OF TRACE-METAL REACTIVE UPTAKE IN THE HYPORHEIC ZONE ON REACH-SCALE METAL TRANSPORT IN PINAL CREEK, ARIZONA

Fuller, C.C.; J.W. Harvey

U.S. Geological Survey Toxic Substances Hydrology Program: Proceedings of the Technical Meeting, 8-12 March 1999, Charleston, South Carolina. Volume 1: Contamination From Hard-Rock Mining

U.S. Geological Survey Water-Resources Investigation Report 99-4018A, p 163-172, 1999

The extent of hydrologic exchange between surface water and the streambed and the rate of trace metal uptake by hyporheic sediments was evaluated in Pinal Creek, Arizona. Trace metal uptake was quantified by measuring a conservative tracer injection into the stream and metal concentrations in the hyporheic zone. Fractional reactive uptake of metals entering the hyporheic zone averaged 55, 27, and 39 percent for cobalt (Co), nickel (Ni), and zinc (Zn), respectively, at 29 sites. Manganese (Mn) uptake averaged 24 percent at the same sites. First-order rate constants (k_1) of metal uptake in the hyporheic zone were determined at seven sites. Reaction-time constants ($1/k_1$) averaged 0.41, 0.84, and 0.38 hours for Co, Ni, and Zn, respectively, and 1.3 hours for Mn. Overall a trend of increased metal uptake with increasing Mn uptake was observed. Laboratory metal uptake experiments with streambed sediments indicate that metal removal increased with pre-existing Mn oxide concentration, suggesting that the enhanced Mn oxidation in the hyporheic zone contributed to trace metal uptake. Surface-water metal concentrations were simulated over a 2.8-km reach using the average k_1 coupled with hydrologic parameters derived from modeling in-stream tracer experiments. Simulations of Mn and Ni using the average k_1 indicated that reactive uptake in the hyporheic zone could account for the net uptake of Mn and Ni downstream over this reach. Simulations of Co and Zn indicated that the extent of uptake in the hyporheic zone could not be accurately distinguished from conservative transport. Uncertainties in defining metal inflows, however, limited the accuracy of reach-scale simulations for Co and Zn. More Info:

<http://toxics.usgs.gov/pubs/wri99-4018/Volume1/index.html>

LIMIT TO SELF-NEUTRALIZATION IN ACID MINE TAILINGS: THE CASE OF EAST-SULLIVAN, QUÉBEC, CANADA

Germain, M.D., Tassé, N., Bergeron M.

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Environmental Geochemistry of Sulfide Oxidation

American Chemical Society, Symposium Series 550, p 365-379, 1994

Near-surface pore waters of the East-Sullivan tailings are enriched in H⁺, Fe²⁺, and SO₄²⁻ by sulfide oxidation. As the pore waters percolate downward, calcite dissolution results in an increase in pH and a release of Ca²⁺, bringing the pore water in the stability field of siderite and gypsum with concomitant precipitation of Fe²⁺, SO₄²⁻ and heavy metals. Locally, however, insufficient amounts of carbonate minerals are dissolved and high concentrations of metals and SO₄²⁻ reach the saturated zone. Negative environmental effects are observed in the tailings-water discharge area around the impoundment; Fe²⁺ is oxidized by atmospheric O₂ and precipitated as Fe(OH)₃ (or a similar phase), generating acidic waters. The situation is expected to worsen, because the jarosite cements, precipitated in the early stages of tailing alteration and limiting O₂ diffusion, are now undergoing dissolution. Furthermore, the calcite reservoir within the tailings decreases with the steady progress of sulfide oxidation.

USE OF CHLOROFLUOROCARBONS, DISSOLVED GASES, AND WATER ISOTOPES TO CHARACTERIZE GROUND-WATER RECHARGE IN AN AQUIFER CONTAMINATED BY ACIDIC, METAL-LADEN WASTEWATER

Glynn, P.D.; Eurybiades Busenberg; J.G. Brown

U.S. Geological Survey Toxic Substances Hydrology Program: Proceedings of the Technical Meeting, 8-12 March 1999, Charleston, South Carolina. Volume 1: Contamination From Hard-Rock Mining

U.S. Geological Survey Water-Resources Investigation Report 99-4018A, p 155-162, 1999

Chemical and isotopic analyses of ground waters sampled from the Pinal Creek Basin, near Globe, Arizona, between 1991 and 1998 provide valuable information on this highly transient ground-water flow system. Improved knowledge of the flow system and of the recharge processes affecting it is essential in predicting the chemical evolution and migration of the extensively contaminated waters in the basin. Data for dissolved nitrogen and argon indicate that most of the ground-water recharge occurs very rapidly during floods in the winter and early spring. Ground-water samples collected in 1991 have chlorofluoro- carbon ages that generally increase with depth and distance downgradient in the metal- and acid-contaminated ground waters. The ground-water ages calculated from chlorofluorocarbon-11 concentrations are reasonable—3 to 15 years for acidic ground waters and 20 to 30 years for neutralized, contaminated ground waters. Ground waters sampled in 1993 have chlorofluorocarbon ages as much as 8 years younger than the waters sampled in 1991. Ground waters sampled in 1996 and in 1998 show that the age of waters in the acidic zone of the system increased by as much as 7 years. Deuterium and oxygen-18 isotope contents measured in the ground waters and their correlation with the specific conductance of the sampled ground waters support the hypothesis that Webster Lake was a major source of metal and acid contamination of ground water in the Pinal Creek Basin. The ground-water ages presented here, however, cannot be used to determine the age of the ground-water solutes introduced by the copper mining and refining operations because the introduced solutes are affected by water-rock reactions and because of remaining uncertainties concerning the application of the chlorofluorocarbon dating technique in this extensively contaminated and highly transient ground-water system. More Info:

<http://toxics.usgs.gov/pubs/wri99-4018/Volume1/index.html>

TRANSPORT AND FATE OF ZN AND CU RICH, LOW PH WATER IN SURFACE AND GROUND WATER FROM PORPHYRY COPPER AND RELATED ORE DEPOSITS, BASIN AND RANGE PROVINCE, SOUTHEASTERN ARIZONA

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Fifth International Conference on Acid Rock Drainage, 20-26 May 2000, Denver, CO

Society for Mining, Metallurgy, and Exploration, Inc. (SME), Littleton, CO. ISBN: 0-87335-182-7. Vol 1, p 411-430, ©2000

Understanding sources of dissolved metals and transport characteristics of acid drainage is needed to assist land-use strategies in mineralized regions, particularly in the semi-arid southwestern US. Water-quality samples were collected from mined and un-mined parts of the Patagonia and southern Santa Rita Mountains of southern Arizona from streams, springs, seeps, adits, alluvial wells, and bedrock wells. Water quality during base-flow conditions was compared with that of runoff samples from infrequent winter and summer storms. The largest fraction of annual discharge in these ephemeral streams consists of storm runoff, although springs provide a steady source of low discharge base flow to numerous intermittent perennial reaches. Several abandoned mines in the northern Patagonia Mountains contribute acid and heavy metals to streams. During base-flow conditions in mineralized areas, natural springs and intermittent stream reaches produce acidity but the volume is typically low and acidity is often diluted or neutralized

down gradient.

WATER-ROCK INTERACTION, ORE DEPOSITS, AND ENVIRONMENTAL GEOCHEMISTRY: A
TRIBUTE TO DAVID A. CRERAR

Hellmann, R.; S.A. Wood (eds.)

The Geochemical Society, St. Louis, MO (gsoffice@gs.wustl.edu). To be published in 2001.

EFFECT OF DISSOLVED MATTER ON FE (II) TRANSPORT IN GROUNDWATER

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AL/EQ-TR-1996-0050. NTIS: ADA356270. 23 pp, Feb 1997

As the focus of ground-water remediation efforts shifts increasingly towards natural attenuation as an alternative method for documenting and quantifying such intrinsic remediation. One indicator of natural attenuation under iron-reducing conditions is concentration of dissolved Fe(II). However, if Fe(II) is to be used to quantify the degradation of ground-water contaminants the process controlling Fe(II) transport in the subsurface must be better understood. Dissolved metals, such as Fe (II) can interact with dissolved organic matter (DOM) to produce both mobile and immobile complexes. These complexes may display sorptive characteristics different than those of the dissolved metal alone, thus potentially facilitating or retarding transport of the metal. Microcosm sorption studies were conducted to determine the effects of DOM on Fe (II) sorption to aquifer solids from 3 U.S. Air Force Bases as a functional of ionic strength (I). DOM at a concentration of 32 mg TOC/L resulted in a marked increase in the sorption of Fe(II) to each of the aquifer solids at I=0.01 M, as judged by Freundlich non-linear isotherm fits of the data. Sorption of Fe(II) in the presence of DOM at I=0.01 also increased over that of DOM-free systems but was less than that in the I=0.01 5 stems, indicating an inverse relationship between Fe(II) sorption and ionic strength. The full text of the report is available through the DTIC search engine at http://www.dtic.mil/stinet/str/tr_fields.html.

ESTIMATING THE ENVIRONMENTAL BEHAVIOR OF INORGANIC AND ORGANOMETAL
CONTAMINANTS: SOLUBILITIES, BIOACCUMULATION, AND ACUTE AQUATIC TOXICITIES

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U.S. Geological Survey Toxic Substances Hydrology Program: Proceedings of the Technical Meeting, 8-12 March 1999, Charleston, South Carolina. Volume 2: Contamination of Hydrologic Systems and Related Ecosystems

U.S. Geological Survey Water-Resources Investigation Report 99-4018B, p 477-482, 1999

The estimation of environmental properties of inorganic species has been difficult. In this presentation, aqueous solubility, bioconcentration and acute aquatic toxicity are estimated for inorganic compounds using existing Linear Solvation Energy Relationship (LSER) equations. Many estimations fall within an order of magnitude of the measured property. For complex solution chemistry, the accuracy of the estimations improve with the more complete description of the solution species present. The toxicities also depend on an estimation of the bioactive amount and configuration. A number of anion/cation combinations (salts) still resist accurate property estimation, and the reasons currently are not understood. These new variable values will greatly extend the application and utility of LSER for the estimation of environmental properties. More Info: <http://toxics.usgs.gov/pubs/wri99-4018/Volume1/index.html>

MECHANISMS CONTROLLING METAL RELEASE IN MILL TAILINGS

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Fifth International Conference on Acid Rock Drainage, 20-26 May 2000, Denver, CO

Society for Mining, Metallurgy, and Exploration, Inc. (SME), Littleton, CO. ISBN: 0-87335-182-7. Vol 1, p 107-114, ©2000

At the Kidd Creek site, natrojarosite residue, derived from the zinc refinery circuit, is mixed with mill tailings before final disposal in the tailings impoundment. Column experiments were conducted with fresh unoxidized mill tailings and a mixture of tailings containing the natrojarosite residue. Acidic water, simulating mine drainage water, was pumped through the columns. The effluent water geochemistry was interpreted with the assistance of MINTEQA2. The experimental results suggest that the effluent water pH was buffered by a series of acid neutralization reactions. The release of metals, including Cu, Pb, and Zn, was affected by pore water pH, Eh, and mineralogy of the tailings material.

MODERN MERCURY CONTAMINATION FROM HISTORIC AMALGAMATION MILLING OF SILVER-GOLD ORES IN THE CARSON RIVER, NEVADA AND JORDAN CREEK, IDAHO: IMPORTANCE OF SPECIATION ANALYSIS IN UNDERSTANDING THE SOURCE, MOBILITY, AND FATE OF POLLUTED MATERIALS

Lechler, P.J.

Mercury Contaminated Sites: Characterization, Risk Assessment, and Remediation
Springer, New York. ISBN: 3540637311. p 337-356, c1999

GEOCHEMICAL FEATURES OF WATER-ROCK INTERACTIONS AT THE SULPHUR BANK MERCURY MINE, LAKE COUNTY, CALIFORNIA

Lechler, P.J. (Nevada Bureau of Mines and Geology, Reno); D.G. Jewett (National Risk Management Research Lab., Ada, OK. Subsurface Protection and Remediation Div.)

EPA 600-A-99-078. NTIS: PB2000-101743. 10 pp, 1999

The Sulphur Bank Mercury Mine on the eastern shore of Clear Lake is the source of poor quality acid mine drainage seeping into Clear Lake. Lateral and vertical geochemical trends in ground water composition point to a number of redox reactions taking place as a function of subsurface water-rock interactions. An understanding of these reactions suggests opportunities to remediate the acid mine drainage through suppression of undesirable geochemical reactions. Two geochemically based remediation steps are proposed.

FATE, BIOAVAILABILITY AND EFFECTS OF METALS IN RIVERS AND ESTUARIES: ROLE OF SEDIMENTS

Luoma, S.N.; M. Hornberger; D.J. Cain; C. Brown; B.-G. Lee; E.V. Axtmann

U.S. Geological Survey, Menlo Park, CA

Proceedings of the U.S. Geological Survey (USGS) Sediment Workshop, February 4-7, 1997

Determinations of metal concentrations in suspended and bed sediments are useful in understanding processes that affect metal contamination in rivers and estuaries. Metal concentrations in sediments can be influenced by variations in sediment texture, composition of sediment, reduction/oxidation reactions, adsorption/desorption, and physical transport or sorting, as well as anthropogenic metal inputs. As a combined result of the influence of the above processes, fluctuation of the metal concentrations of

sediments occurs in time and space and bioavailability from sediments changes. The relative importance of individual processes is determined by the geochemistry of the specific metal or metalloid and the characteristics of the ecosystem. A variety of strategies can improve the comparability of metal determinations in sediments, improve understanding of anthropogenic contributions to concentrations, and define deviations from background concentrations. Studies of metal concentrations in suspended and bed sediments have examined the interacting influences on metal concentrations of geologic inputs, anthropogenic contamination, riverine inflows and geochemical processes (for example, desorption/adsorption at the freshwater/seawater interface). Sediment data are also being employed in studies of metal bioavailability to resident species. This paper is available at <http://water.usgs.gov/osw/techniques/workshop/Hornberger.html>

ENVIRONMENTAL FACTORS AFFECTING OXIDATION OF MANGANESE IN PINAL CREEK, ARIZONA

Marble, J.C.; T.L. Corley; M.H. Conklin; C.C. Fuller

U.S. Geological Survey Toxic Substances Hydrology Program: Proceedings of the Technical Meeting, 8-12 March 1999, Charleston, South Carolina. Volume 1: Contamination From Hard-Rock Mining

U.S. Geological Survey Water-Resources Investigation Report 99-4018A, p 173-184, 1999

The objectives of the laboratory work reported here were to quantify the net rates of removal of manganese [Mn(II)] by streambed sediments collected from a metals contaminated, perennial stream system (Pinal Creek near Globe AZ) and to determine the key variable(s) responsible for the limited removal of Mn(II) observed at this field site. Pinal Creek is characterized by significant spatial gradients in pH, alkalinity, and Mn(II) along its length and by spatial gradients in pH, dissolved oxygen, and Mn(II) across hyporheic zones of varying thickness. These gradients are established by mixing of surface water and entering shallow ground water in the sediments. The mixing of waters in the hyporheic zones define the local chemical environments in which Mn(II) is removed by incorporation into pre-existing and newly formed mineral surfaces through abiotic and biotic processes. As a consequence of the site characteristics, particularly the spatial gradients in the hyporheic zone, the primary chemical parameters included in the test matrix were pH, initial Mn(II) concentration, and dissolved oxygen. Streambed sediments collected from the site were used in laboratory batch investigations of the rate of Mn(II) removal. Results of these studies indicate that

removal of Mn(II) within the hyporheic zone primarily occurs via biotic oxidation processes, is approximately first-order with respect to the Mn(II) concentration and inversely proportional to $[H^+]$, and independent of dissolved oxygen concentration except at very low levels. More Info:

<http://toxics.usgs.gov/pubs/wri99-4018/Volume1/index.html>

HYDROGEOCHEMISTRY OF OXIDISED WASTE ROCK FROM STRATMAT SITE, N.B.

MEND Secretariat CANMET, Ottawa, Ontario. MEND Report 2.36.2a, Mar 1999

This report documents the results of the first part of a research project jointly funded by Noranda Inc. and the Mine Environment Neutral Drainage (MEND) program. The second part is covered in a separate report entitled *Hydrology and Solute Transport in Oxidised Waste Rock from Stratmat Site, N.B.*, published concurrently with this report (MEND 2.36.2b). The overall objective of the project was to understand the geochemical and hydrological interactions between the partially oxidised waste rock and water and to improve our capabilities and techniques in the prediction of acidic drainage from waste rock piles. Partially oxidised waste rock was sampled from the Stratmat pile at Heath Steele Division of Noranda, Inc., by grabbing, trenching, and bulk excavation techniques. The samples were physically and

geochemically characterised in the laboratory, whereas the bulk density was measured in the field. The trenched samples were used in column dissolution tests in which 25-kg composite sub-samples were subjected to repeated washing with water to observe the water quality evolution over time. The resulting data were used to predict water quality for a hypothetical scenario where the waste rock were backfilled in the Stratmat pit. In addition, water quality profiles were measured in the Stratmat pit.

HYDROLOGY AND SOLUTE TRANSPORT OF OXIDISED WASTE ROCK FROM STRATMAT SITE, N.B.

MEND Secretariat CANMET, Ottawa, Ontario. MEND Report 2.36.2b, Mar 1999

This report documents the results of the second part of a research project jointly funded by Noranda Inc. and the Mine Environment Neutral Drainage program. The first part is covered in a separate report entitled *Hydrogeochemistry of Oxidised Waste Rock from Stratmat Site, N.B.*, published concurrently with this report (MEND 2.36.2a). The overall objective of the project was to understand the geochemical and hydrological interactions between partially oxidised waste rock and water, and to improve our capabilities and techniques in the prediction of acidic drainage from waste rock piles. The main objective of this part of the research was to understand the hydrology and solute transport within waste rock piles during infiltration and drainage events in response to precipitation. Large column tests were conducted to achieve this objective. Three columns measuring 1.2 m in diameter and 2 m in height and containing up to 3.7 t of partially oxidised Stratmat waste rock were subjected to ten rain simulations. The bottom area of each column was divided into drainage partitions. During and after each rain simulation, the volume and the chemistry of the drainage in each partition was monitored independently over time.

LABORATORY STUDY OF PARTICLE RESUSPENSION, OXIDATION AND METAL RELEASE IN FLOODED MINE TAILINGS

Rapport NEDEM 2.15.3, Nov 1998

MEND Secretariat CANMET, Ottawa, Ontario (mend@nrnl.nrcan.gc.ca)

The use of shallow water cover (up to 2 m) to flood reactive sulphide mine tailings is a popular method of acid drainage prevention used by the mining industry. In flooded tailings, wind-induced turbulence can increase the oxygen flux from air into water by creating turbulence at the air-water interface, thus promoting mechanical mixing of oxygen from air into the water and thus keeping the dissolved oxygen concentrations at saturation levels. Turbulence can also resuspend tailings particles in the oxygen-saturated water cover and expose tailings to greater contact with oxygen, possibly leading to increased oxidation and metal release. In late 1996, the Geotechnical Research Centre at The University of Western Ontario initiated a study to investigate the contribution of resuspension to tailings oxidation and acid generation under laboratory conditions. The study was undertaken on behalf of MEND and sponsored by Battle Mountain Canada Limited, Falconbridge Limited, INCO Limited, Noranda Mineral and Exploration Limited, Teck Corporation, Ontario Ministry of Northern Development and Mines and Canada Centre for Mineral and Energy Technology (CANMET) through the CANADA/Northern Ontario Development Agreement (NODA). This report presents the results of the study.

GEOCHEMICAL ASSESSMENT OF SUBAQUEOUS TAILINGS DISPOSAL IN ANDERSON LAKE, MANITOBA: 1993-1995 STUDY PROGRAM

MEND Secretariat CANMET, Ottawa, Ontario. MEND Report 2.11.3, Aug 1996

Sulphide-rich zinc-, copper-, and lead-bearing tailings have been deposited via floating pipeline

into shallow (< 8 m) Anderson Lake in north-central Manitoba since 1979. The lake water contains elevated levels of dissolved metals which are derived mainly from an acid-generating roadway along the north shore. Watercolumn sampling and sediment coring were carried out through the ice on Anderson Lake in April 1993. Two sites were occupied, one proximal to the tailings discharge (Station B, the "pure tailings" site) and the other about 2 km away (Station A, the "natural sediments" site). Interstitial waters were extracted from duplicate cores collected at each location. The water column was strongly stratified at both locations, exhibiting four layers at the natural sediments site (two of which were dysaerobic or anoxic), and two layers near the tailings outfall, the lower being dysaerobic. The unusual multiple layering probably reflects the influence of laterally variable advective processes. High concentrations of dissolved iron in shallow pore waters indicate that the sediments at both locations were anoxic at shallow subsurface depths. Concentrations of Zn, Cu, Pb and Cd were very low or undetectable in the pore waters. There was no evidence of release of Cu, Cd or Pb from the deposited tailings, although there was evidence of possible minor release of Zn from surface sediments in one of the tailings cores. Metals were removed from pore waters below the upper 10 cm at both sites, which is attributed to precipitation of authigenic sulphide phases.

HYDROGEOLOGY OF WASTE ROCK DUMPS

MEND Secretariat CANMET, Ottawa, Ontario. MEND Associate Project PA-1, Jul 1995

Predictions of whether and when a waste rock pile may start to generate acidic water, and how long a pile may release elevated concentrations of metals to the environment, are related on a fundamental level to an understanding of fluid flow within a waste rock pile. Our analysis of the hydrogeological properties of waste rock piles is based on a synthesis of data from four mine sites; Myra Falls, B.C., Island Copper, B.C., Elkview Mine, B.C., and Golden Sunlight Mine, Montana. The emphasis in this study is on pile hydrostratigraphy and the textural properties of the rock mass, spatial and temporal variations in water content within a waste rock pile, temperature profiles within a waste rock pile and their response to the infiltration of water following a rainfall event, and the large-scale hydrogeologic characterization of a waste rock pile inferred from outflow hydrographs recorded in toe drains.

ENVIRONMENTAL GEOCHEMISTRY OF MINESITE DRAINAGE: PRACTICAL THEORY AND CASE STUDIES

Morin, Kevin A.; Nora M. Hutt

Minesite Drainage Assessment Group, Vancouver, BC

MDAG Publishing, Vancouver, BC, Canada. ISBN: 0-9682039-0-6. 356 pp, 1997

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The study of drainage chemistry at mines and mining operations is expanding rapidly, particularly for acidic drainage. Although there have been many conferences and symposia on minesite drainage, there has been no book that compiles and interprets the relevant theory and international case studies. To fill the need, Kevin Morin and Nora Hutt examined nearly 360 references and 92 supporting international case studies to produce this book. All types of drainage are examined, from acidic to alkaline drainage, and brine-like drainage from evaporite mining. Acidic drainage is emphasized because of the overwhelming number of papers and reports on it. The practical theory and case studies are highlighted with tables and figures, and drainage chemistry from open pits, underground workings, waste-rock dumps, ore stockpiles, and tailings impoundments are discussed. Appendices include a glossary and internationally accepted methods for predictive tests. There are indexes for subjects, minesites, case studies, and authors. Environmental Geochemistry of Minesite Drainage: Practical Theory and Case Studies is designed to serve

three purposes. First, it is a guidebook for assessing, predicting, and controlling minesite-drainage chemistry. Second, it is a reference book illustrating the current level of knowledge and directing the reader toward valuable references for further details. Third, it is a textbook for students learning drainage chemistry, with questions at the end of each chapter to highlight important issues and to provoke further thought. The book therefore offers many benefits for beginners to experts in the field of minesite-drainage chemistry.

MINE WASTE ROCK PILE GEOCHEMISTRY AND MINERALOGY IN SOUTHWESTERN NEW MEXICO, USA

Munroe, E.A.; V.T. McLemore; N.W. Dunbar

Fifth International Conference on Acid Rock Drainage (ICARD), 21-24 May 2000, Denver, Colorado
Society for Mining, Metallurgy, and Exploration (SME), Inc., Littleton, CO, ISBN: 0-87335-182-7. Vol 2, p 1327-1336, 2000

In New Mexico, there are at least 100,000 abandoned mine waste rock piles with widely ranging geochemical and mineralogical compositions. A geochemical and mineralogical study was implemented for five waste rock piles, some which contained sulfides, in the Hillsboro Mining District. Chemical and physical characteristics of mineral grains and their secondary mineral oxidation rinds were examined with the electron microprobe. Pyrite and chalcopyrite appear to be the most reactive to oxidizing conditions. Clays, iron oxide, iron hydroxide, iron sulfate, and primary texture rinds exist in the waste rock piles analyzed.

METAL LEACHING FROM SULFIDE MINE WASTE UNDER NEUTRAL PH CONDITIONS

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Fifth International Conference on Acid Rock Drainage (ICARD), 21-24 May 2000, Denver, Colorado
Society for Mining, Metallurgy, and Exploration (SME), Inc., Littleton, CO, ISBN: 0-87335-182-7. Vol 2, p 951-958, ©2000

Waste rock and tailings from a proposed nickel-copper mine were evaluated extensively for potential on-land and underwater disposal. Standard humidity cell and column tests were conducted over a two-year period and underwater tests were conducted for more than one year. Nickel concentrations or release rates from the waste were consistent with nickel to sulfur ratios in the solids. This relationship provided a tool to assess the risk of metal leaching in wastes using nickel and sulfide assays. Nickel release and mobilization was found to occur for both oxidizing leach tests and underwater tests even when pH values exceeded 7.0. Geochemical model calculations showed that iron oxyhydroxide solids can scavenge nickel from leachate and that the nickel inventory can be released from solids at relatively lower, but neutral pH values.

GEOCHEMICAL BEHAVIOUR OF SUBMERGED PYRITE-RICH TAILINGS IN CANADIAN LAKES

Pedersen, T.F.; J.J. McNee; D.H. Flather, et al.

Acidic Mining Lakes: Acid Mine Drainage, Limnology, and Reclamation
Springer, New York. ISBN: 354063486X. p 87-126, c1998

MOBILITIES OF HEAVY METALS IN SURFACE WATERS: A FIELD STUDY OF MINERAL BRANCH, TRI-STATE MINING DISTRICT

Piechowski, M.F.; S.A. Carroll

Geological Society of America, Abstracts with Programs, Vol 247, p A33-A34, 31 Jan 1992

A field study of the mobilities of heavy metals was done in the Tri-State Mining District near Joplin, Missouri. The processing of ores left many large tailings piles in this region which are predominantly chert, but contain minor amounts of carbonate and sulfide minerals. The residual sphalerite, galena, marcasite, and pyrite readily dissolve when exposed to surface waters, increasing the acidity and concentrations of Pb, Zn, and Cd in the streams of the region. Mineral Branch is a local stream that originates in and flows through a tailings field. Water and sediment (bed and suspended load) samples were collected and analyzed by ICP and XRD methods in order to determine trace and major element concentrations and mineral compositions, respectively. The solids are primarily chert and carbonates, with small amounts of crystalline and amorphous iron hydroxides and oxyhydroxides. Over the two mile study area, pH increases steadily downstream. As the pH rises, the dissolved heavy metal concentrations fall, some by an order of magnitude or more. It was also found that over 99% of the Pb, Zn, and Cd in the system is presents in the solids. Precipitation of carbonates or hydroxides does not adequately explain the concentration changes seen in the system. The adsorption of the metal species onto the carbonates and iron oxyhydroxides of the stream sediments as a function of pH is an additional controlling factor in the Mineral Branch.

METALS IN LAKES: FIELD AND MODELING RESULTS ON REMEDIAL STRATEGIES WITH A FOCUS ON MERCURY AND RADIOCESIUM

Reuther, Rudolf (ed.)

Geochemical Approaches to Environmental Engineering of Metals
Springer, New York. ISBN: 0387588485. Chapter 9, c1996

A HYDROGEOLOGICAL AND GEOCHEMICAL STUDY OF A GOLD MINE TAILINGS-DERIVED PLUME, CAMPBELL MINE, BALMERTOWN, ONTARIO

Ross, C., Master's thesis, Univ. of Waterloo, Waterloo, ON
1998

LEACHING OF METALS FROM SULFIDE MINE WASTES AT NEUTRAL PH

Scharer, J.M. (Univ. of Waterloo, Waterloo, ON); C.M. Pettit; J.L. Kirkaldy; L. Bolduc; B.E.

Halbert; D.B. Chambers (SENES Consultants, Ltd., Richmond Hill, ON)

Fifth International Conference on Acid Rock Drainage, 20-26 May 2000, Denver, CO

Society for Mining, Metallurgy, and Exploration, Inc. (SME), Littleton, CO. ISBN: 0-87335-182-7. Vol 1, p 191-203, ©2000

In contrast to acid mine drainage (AMD), neutral mine drainage (NMD) has not yet received widespread attention. Metal and sulfate concentrations can be elevated and of concern in neutral drainage from waste rock and tailings. In the present paper, metal release in high ionic strength mine drainage at neutral pH is evaluated at several mine sites. Specific factors including oxidation rates, buffering capacity, and hydrology are also addressed and their effect on the production of contaminated NMD from mine wastes is evaluated. Case studies are presented involving current seepage water quality and predictive geochemical modeling.

GEOCHEMICAL PROCESSES AND THE EFFECTS OF NATURAL ORGANIC SOLUTES ON THE SOLUBILITY OF SELENIUM IN COAL-MINE BACKFILL SAMPLES FROM THE POWDER RIVER BASIN, WYOMING

See, R.B.; K.J. Reddy; G.F. Vance; A.A. Fadlilmawla; M.J. Blaylock

USGS Water-Resources Investigations Report 95-4200, 28 pp, 1995

Geochemical processes and the effects of natural organic solutes on the solubility of selenium in coal-mine backfill aquifers were investigated. Backfill and ground-water samples were collected at coal mines in the Powder River Basin, Wyoming. Backfill was generally dominated by aluminum (14,400 to 49,000 mg/kg (milligrams per kilogram)), iron (3,330 to 23,200 mg/kg), and potassium (7,950 to 18,000 mg/kg). Backfill saturated-paste selenium concentrations ranged from 1 to 156 mg/kg (microsiemens per kilogram). Ground-water total selenium concentrations ranged from 3 to 125 mg/L. Dissolved organic carbon in all ground-water samples was dominated by hydrophobic and hydrophilic acids (38 to 84 percent). Selenite sorption/desorption experiments were conducted using background solutions of distilled-deionized water, 0.1 molar calcium chloride, and isolated hydrophobic and hydrophilic acids. Selenite sorption was larger when 0.1 molar calcium chloride was used. The addition of hydrophilic acid decreased selenite sorption more than the addition of hydrophobic acids. Geochemical modeling was used to predict the solid phases controlling dissolved selenium concentrations and to evaluate the effects of dissolved organic carbon on selenium solubility. Results suggested that 55 to 90 percent of selenium in backfill precipitation/dissolution extracts was dominated by magnesium selenate ion pairs. Dissolved organic carbon had little effect on selenium speciation. A redox chamber was constructed to control Eh and pH in water and backfill-core sample suspensions. The response of selenite and selenate in water samples to redox conditions did not follow thermodynamic predictions. Reduction of selenate in water samples did not occur at any of the redox levels tested.

INVESTIGATION OF ACID PRODUCTION, LEACHING, AND TRANSPORT OF DISSOLVED METALS AT AN ABANDONED SULFIDE TAILINGS IMPOUNDMENT: MONITORING AND PHYSICAL PROPERTIES

Stewart, B.M.; B.C. Williams; R.H. Lambeth

Bureau of Mines, Spokane, WA. Spokane Research Center

NTIS: PB96-128582INZ. 90 pp, Apr 1995

MECHANISMS OF RELEASE AND ATTENUATION OF ARSENIC IN GOLD MINE TAILINGS CAMPBELL MINE, BALMERTOWN, ON

Stichbury, Mei-Lin, Master's thesis, Univ. of Waterloo, Waterloo, ON, 2000

The release and attenuation mechanisms of arsenic (As) in the tailings at Campbell Gold Mine, Balmertown, Ontario, were investigated. Arsenic is toxic, therefore, its release and attenuation are concerns with respect to effective, long-term tailings management. The highest concentrations of As were measured at the base of the tailings impoundments and were associated closely with a peat unit. On the South Dam of the Current Impoundment the highest concentration of As measured was 75 mg/L, at the top of the peat. The highest concentration of As recorded on the Balmer tailings was 113 mg/L, also measured at the top of the peat, at the southern end of the impoundment. The high concentrations of As were also associated with high concentrations of dissolved Fe(II), which suggests that As was released by the reductive dissolution of As-bearing Fe(III)-oxides. The decrease in As and Fe concentrations in the zone of greatest SO₄ reduction

suggested these constituents were removed from solution by metal sulfide precipitation. Solid-phase sulfur speciations showed that monosulfides accumulated at the tailings/organic carbon boundary at the South Dam of the Current Impoundment and at the north Balmer tailings location. Near surface analysis of tailings material from the bottom of Current Impoundment by X-ray photoelectron spectroscopy (XPS) indicated that As is bound as a sulfide at this depth. The binding energy for As obtained by XPS was 43.9 eV which corresponds to literature values for the mineral As₂S₃. Dissolved organic carbon (DOC) was demonstrated to be the electron donor for the reduction of Fe(III), SO₄, and DIC.

DETERMINATION OF KINETIC COEFFICIENTS FOR THE SIMULTANEOUS REDUCTION OF SULFATE AND URANIUM BY DESULFOVIBRIO DESULFURICANS BACTERIA

Tucker, M.D., Sandia National Labs., Albuquerque, NM

Report No: SAND-94-0686. NTIS: DE95011839. 45 pp, May 1995

Uranium contamination of groundwaters and surface waters near abandoned mill tailings piles is a serious concern in many areas of the western United States. Uranium usually exists in either the U(IV) or the U(VI) oxidation state. U(VI) is soluble in water and, as a result, is very mobile in the environment. U(IV), however, is generally insoluble in water and, therefore, is not subject to aqueous transport. In recent years, researchers have discovered that certain anaerobic microorganisms, such as the sulfate-reducing bacteria *Desulfovibrio desulfuricans*, can mediate the reduction of U(VI) to U(IV). Although the ability of this microorganism to reduce U(VI) has been studied in some detail by previous researchers, the kinetics of the reactions have not been characterized. The purpose of this research was to perform kinetic studies on *Desulfovibrio desulfuricans* bacteria during simultaneous reduction of sulfate and uranium and to determine the phase in which uranium exists after it has been reduced and precipitated from solution. The studies were conducted in a laboratory-scale chemostat under substrate-limited growth conditions with pyruvate as the substrate.

EVALUATING THE ABILITY OF TRACER TESTS TO QUANTIFY REACTIVE SOLUTE TRANSPORT IN STREAM-AQUIFER SYSTEMS

Wagner, B.J.; J.W. Harvey

U.S. Geological Survey Toxic Substances Hydrology Program: Proceedings of the Technical Meeting, 8-12 March 1999, Charleston, South Carolina. Volume 1: Contamination From Hard-Rock Mining

U.S. Geological Survey Water-Resources Investigation Report 99-4018A, p 201-210, 1999

Tracer experiments are valuable tools for characterizing the fate and transport of solutes carried in stream waters; however, the results can have high uncertainty when the technique is not properly implemented. The goal of this study was to identify the limitations that apply when we couple conservative-tracer injection with reactive solute sampling to identify the transport and reaction processes active in a stream. The conservative-tracer injection is used to characterize the physical transport processes of advection, dispersion, ground-water inflow, and stream-storage exchange (the movement of stream water and solute between the active stream channel and storage zones in the channel margins and in the subsurface). The reactive-solute sampling is used to characterize the removal of reactive solute due to geochemical/biotic processes occurring in the storage zones. We apply the methodology of Wagner and Harvey (1997) to evaluate the tracer approach for the wide range of transport and reaction conditions likely encountered in high-gradient streams. The methodology couples solute transport simulation with parameter uncertainty analysis in a Monte Carlo framework to identify those combinations of stream transport and reaction properties that pose

limitations to the tracer approach. Our results show that the uncertainty associated with determining the reaction rate constant is strongly related to the reactive loss factor, which is a dimensionless combination of the reaction rate constant, the average solute residence time in the storage zone, the experimental reach length, and the average distance travelled by a stream solute before entering a storage zone. As the reactive loss factor increases, the effect of reactive loss in the storage zones along the study reach increases and the uncertainty in the reaction rate estimate decreases. More Info:
<http://toxics.usgs.gov/pubs/wri99-4018/Volume1/index.html>

OXIDATION OF FLOODED MINE TAILINGS DUE TO RESUSPENSION

Yanful, Ernest. K.; Ajay Verma

Canadian Geotechnical Journal, Vol 36 No 5, p 826-845, 1 Oct 1999

Laboratory experiments were performed to assess the contribution of resuspension to the oxidation of pyrrhotite mine tailings flooded with a shallow water cover (up to 80 cm). Resuspension was produced by a paddle rotated at prescribed speeds in the water cover. The quality of the water cover was monitored over a 126 day period and the results were compared to the case where the tailings were kept still (no resuspension). The results showed that resuspended tailings oxidized considerably more than tailings at rest. The pH and dissolved oxygen concentration of the stirred water covers were 2.6 and 14 times lower, respectively, than those of the static water covers where there was no resuspension. Sulphate production increased by about 26-64 times, while the release of metals such as zinc, copper, and nickel was 1020, 318, and 138 times greater, respectively. The suspended tailings were finer and had lower pyrrhotite content at the end of the experiments than the tailings at rest and the original tailings. Tailings oxidation and metal release increased with increasing stirrer speed and decreasing depth of water cover. These findings pertain to laboratory conditions and the water-quality data cannot necessarily be extrapolated to the field, except in a general sense.